Water Cycle and Land-Atmosphere Coupling in CFSv2

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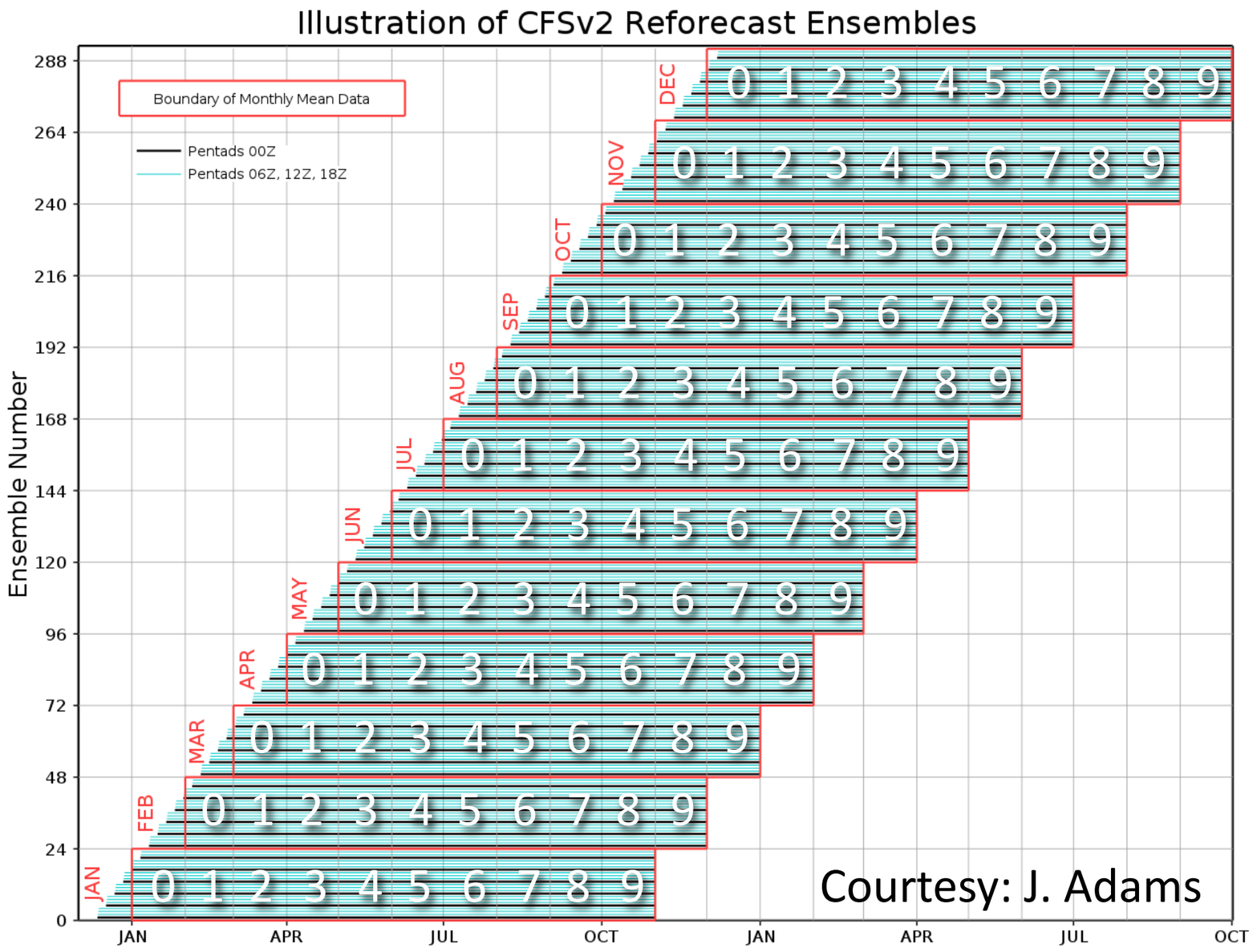
- Water Cycle Drift in Reforecasts
- Land-Atmosphere Coupling
- Land Initial Conditions and Skill

Another View of the CFSR Suite



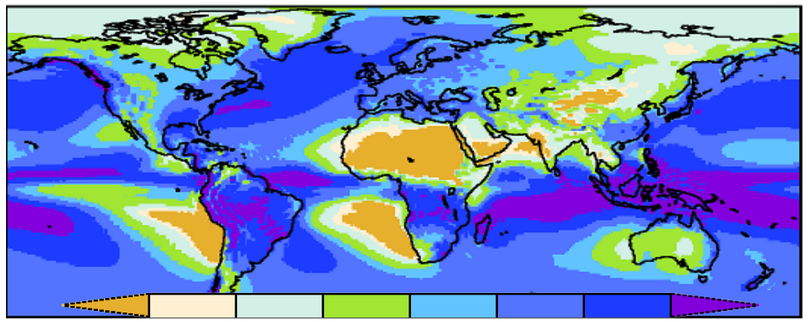
- "0-Lead" starts anywhere from 30 days prior to 7 days into forecast period.
- Four 9-month forecasts started every 5 days.
- 24-28 forecasts per month.
- Creates analysis challenges and opportunities.

Drift in Means, Variances

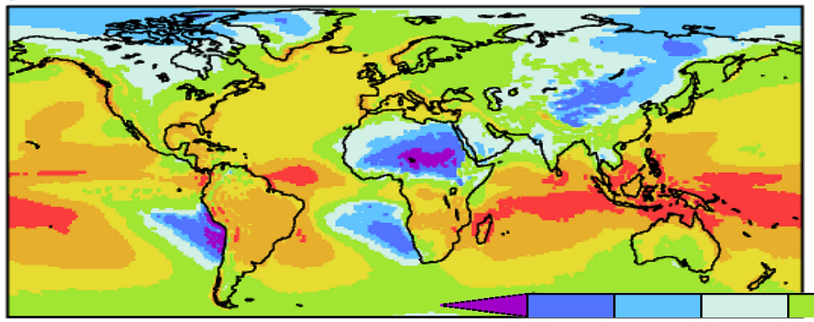
- Next slides show seasonal means of:
  - 0-Lead:
    - Mean global precipitation
    - Intra-ensemble standard deviation (24-28 members for each month)
    - Interannual standard deviation (of ensemble means – the “climate signal”)
  - Differences from 0-Lead at leads of 1, 4 and 8 months.
- Quantities averaged for DJF and JJA seasons.

DJF

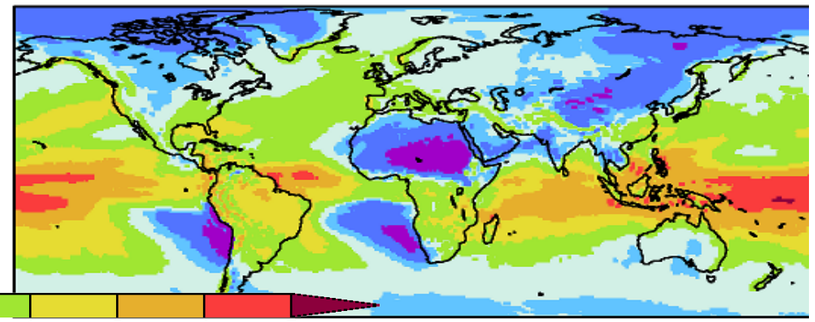
Precip Lead 0



Intra−Ens_StdDev Lead 0

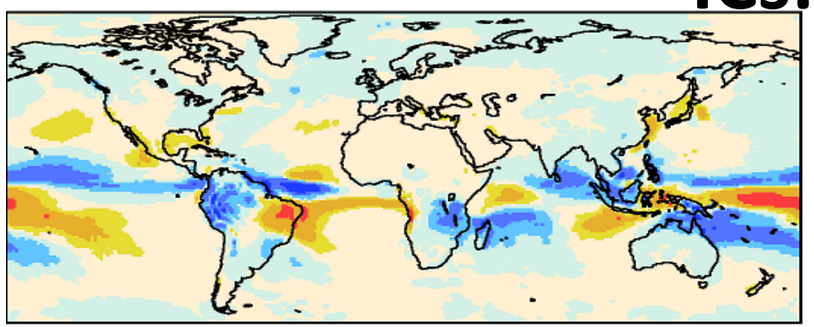


Interannual_StdDev Lead 0



ICs: NDJ

Lead 1



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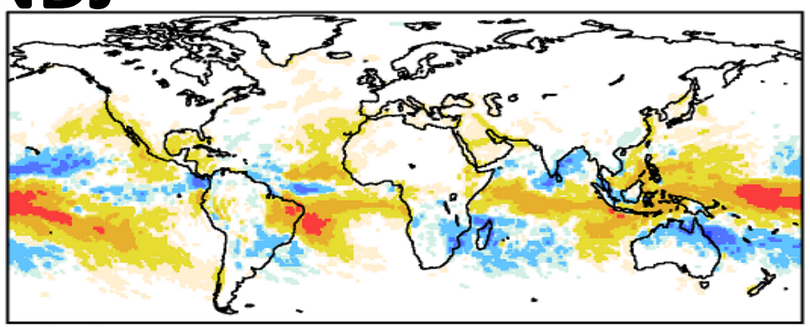
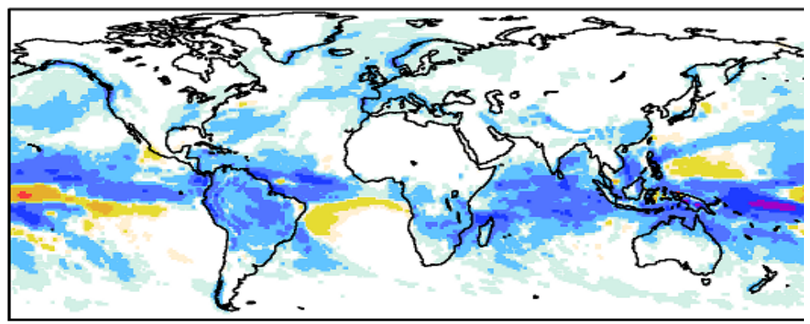
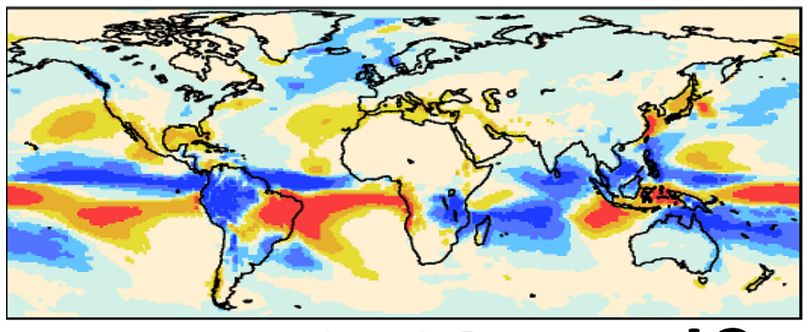


Lead 1

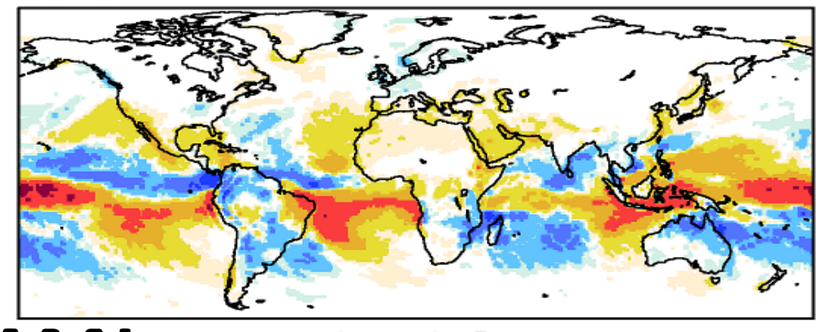


ICs: ASO

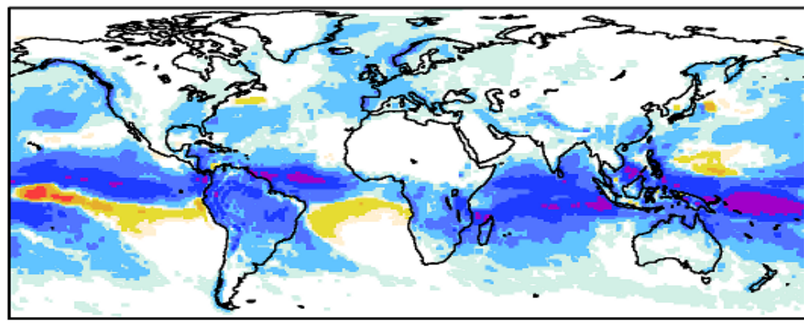
Lead 4



Lead 4

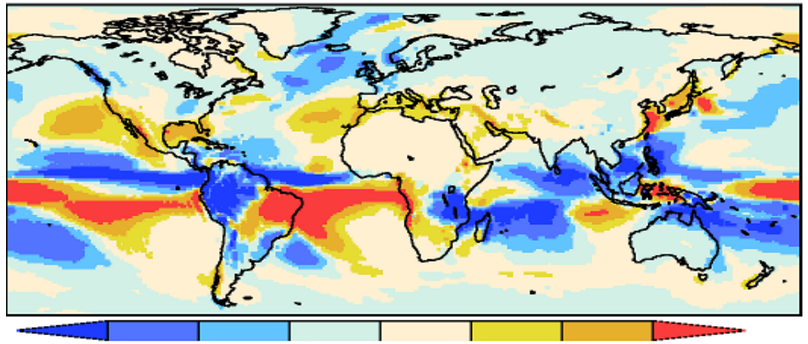


Lead 4



ICs: AMJ

Lead 8



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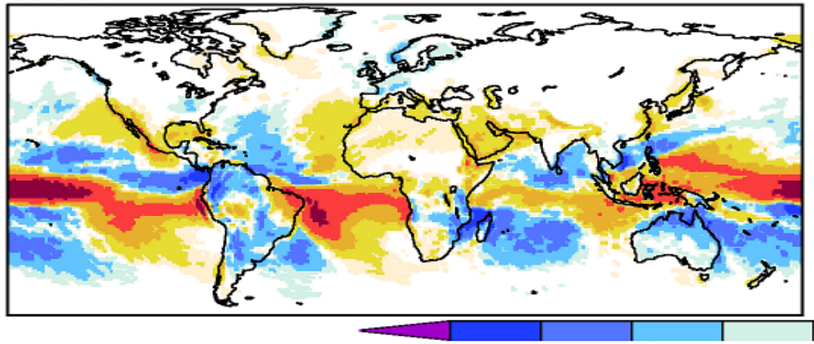

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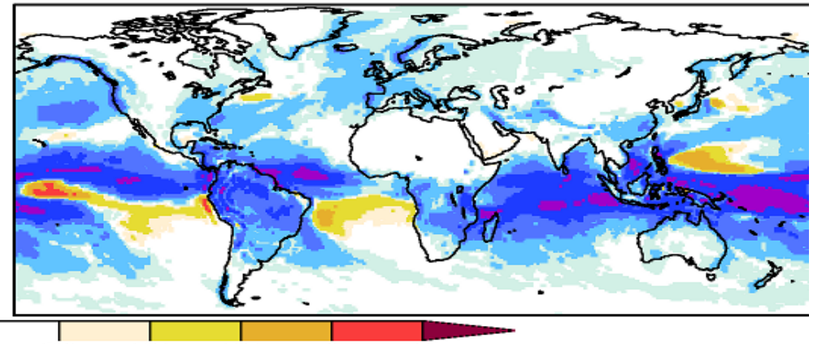
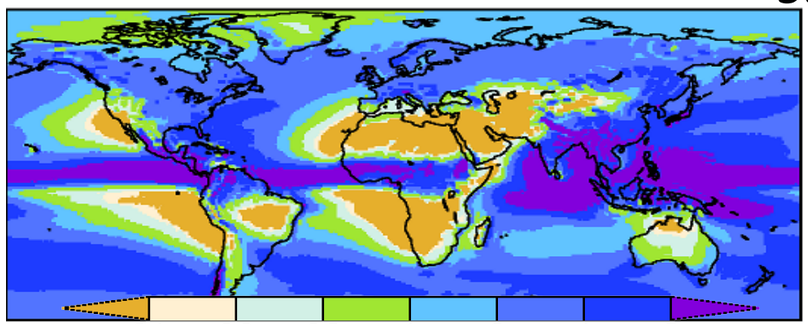


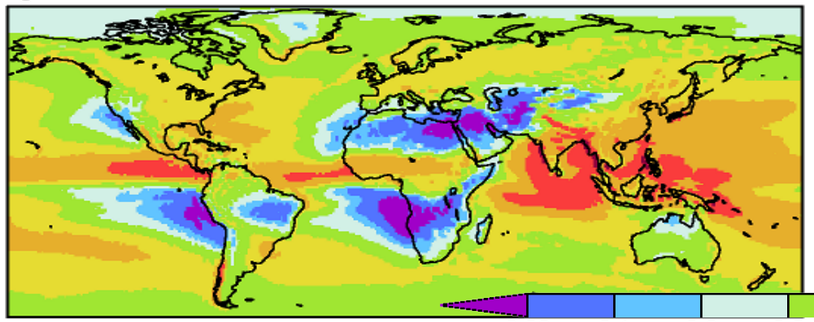
JJA

Precip Lead 0



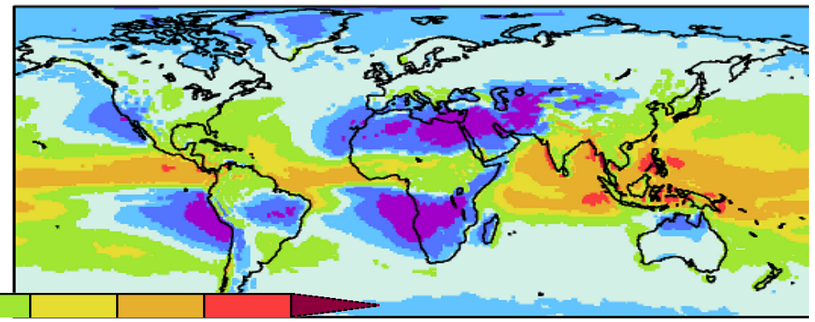
Lead 1

Intra−Ens_StdDev Lead 0



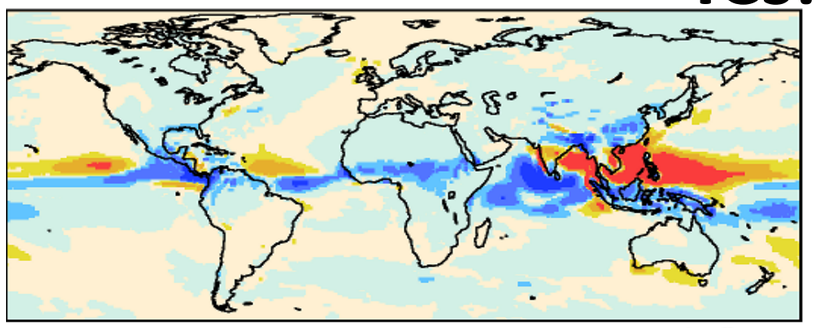
Lead 1

Interannual_StdDev Lead 0



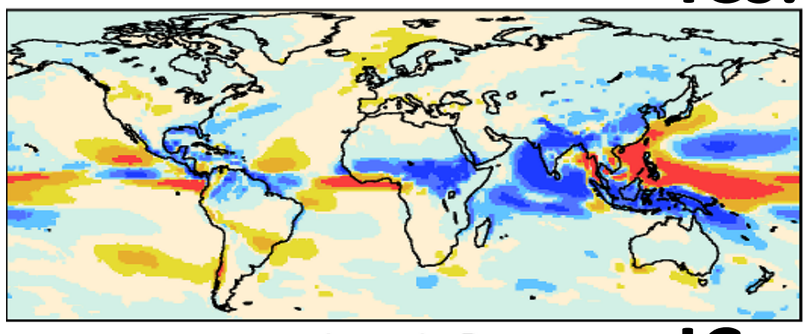
Lead 1

ICs: MJJ



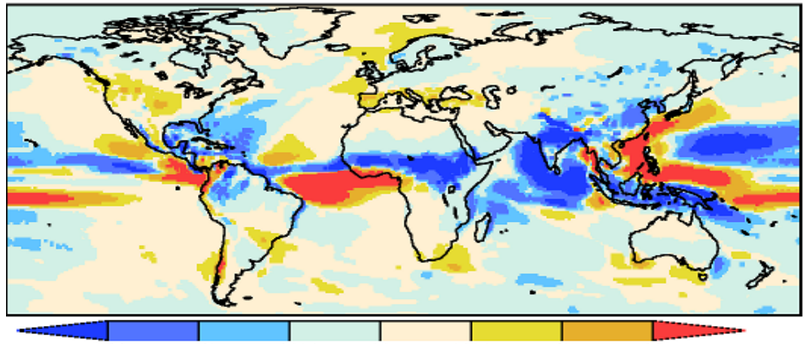
Lead 4

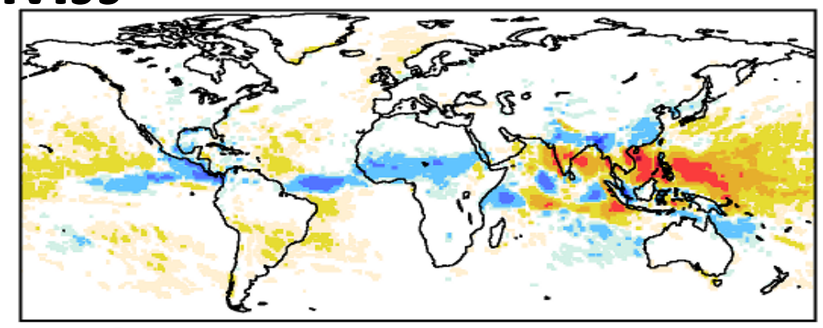
ICs: FMA



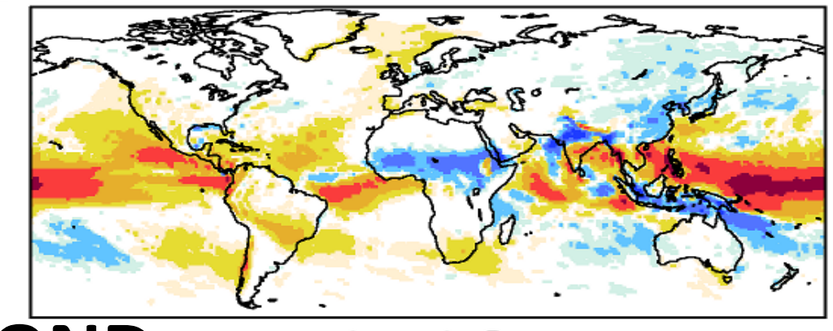
Lead 8

ICs: OND

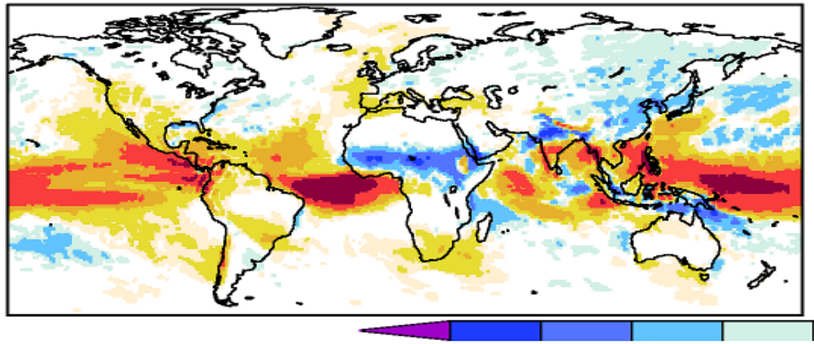


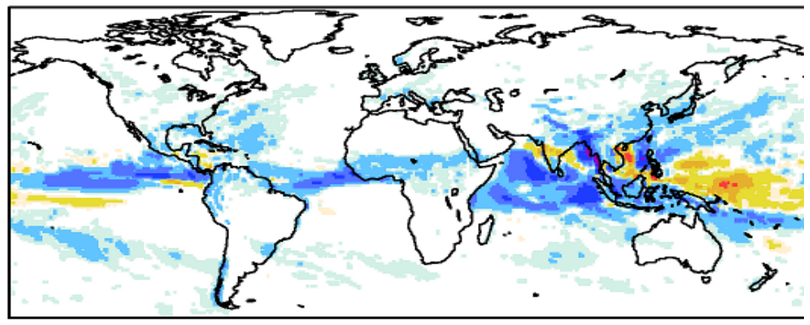


Lead 4

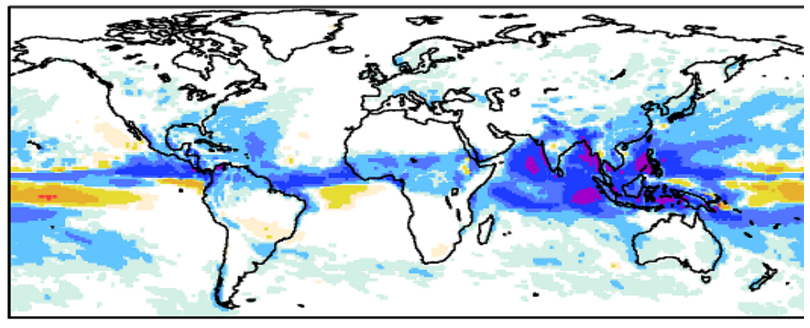


Lead 8

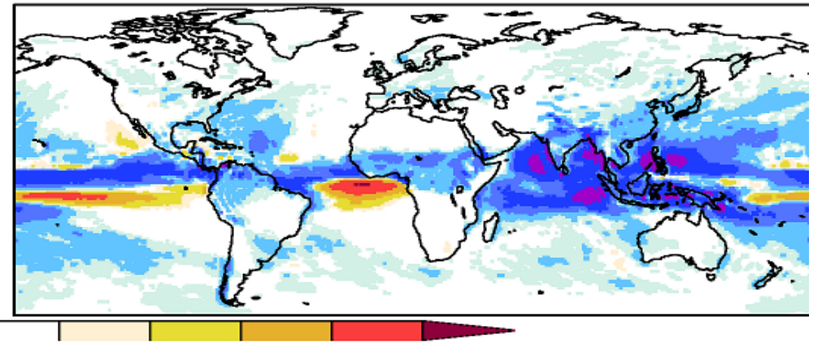




Lead 4



Lead 8

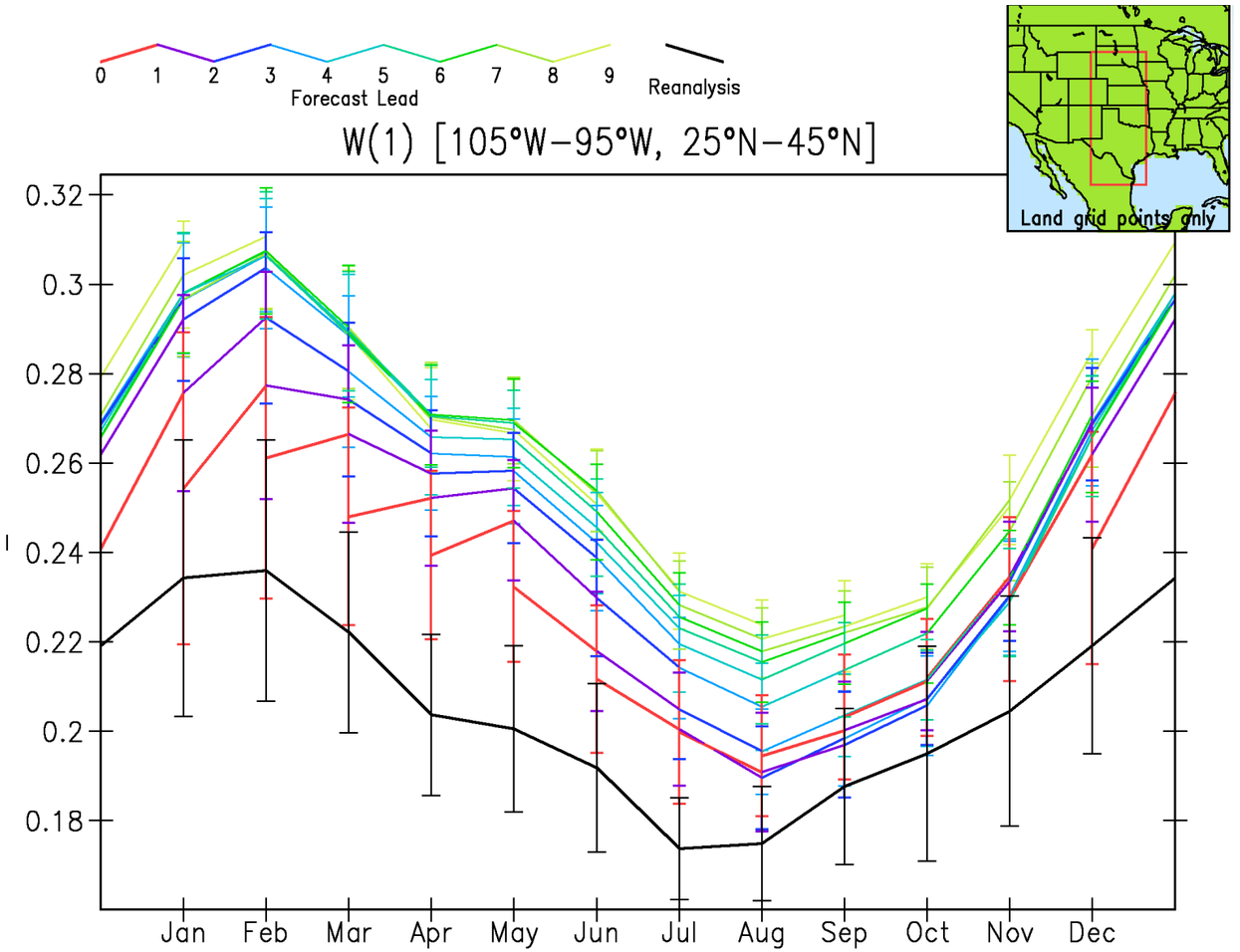


Drift in Means, Variances

- Means show a drift to the CFSv2 model climate
  - Increase in oceanic ITCZ/tropical precipitation
  - Mainly decreases elsewhere (e.g., continents)
- Ensemble spread largely follows mean drift (ocean-driven??).
- Interannual variability decreases markedly with forecast lead.
- Need to consider: **Forecast climatology varies in 2 time dimensions – seasonal cycle and forecast lead**

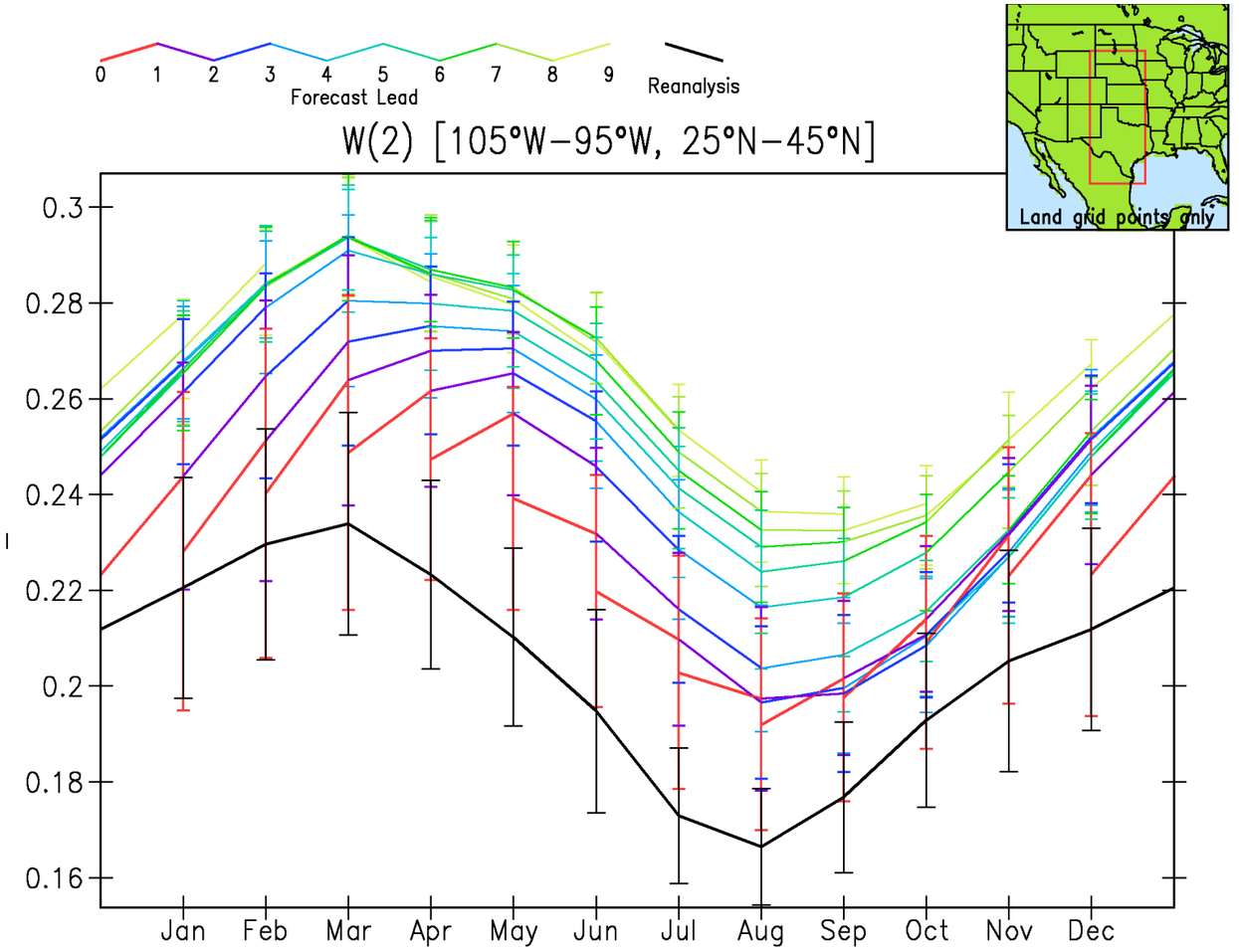
Surface Water Cycle – A Multifarious Tale

- US Great Plains average:
- Surface layer soil moisture quickly drifts towards wet bias
  - Soil moisture initialized from offline Noah run (GLDAS).
  - This is the same stream used to reset CFS reanalysis every 24 hours, so reanalysis (black curve) is constrained by GLDAS.



Wet Bias Exists Throughout Upper Soil

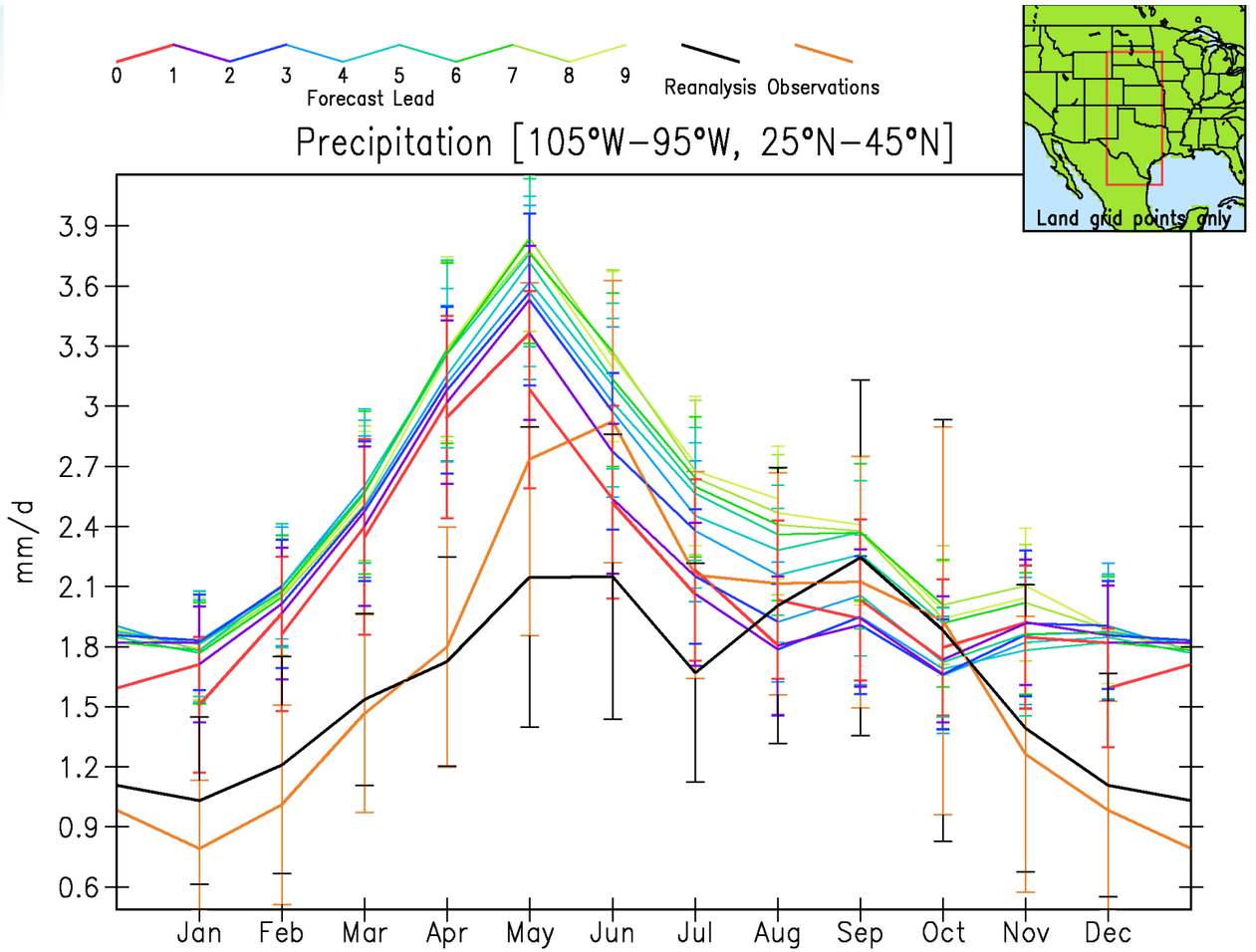
- What is the driver of this drift in the CFS reforecasts?
- What are its implications?



- Note – the bars denote the interannual ±1σ for each forecast at each lead, and for reanalysis.

Culprit is Precipitation

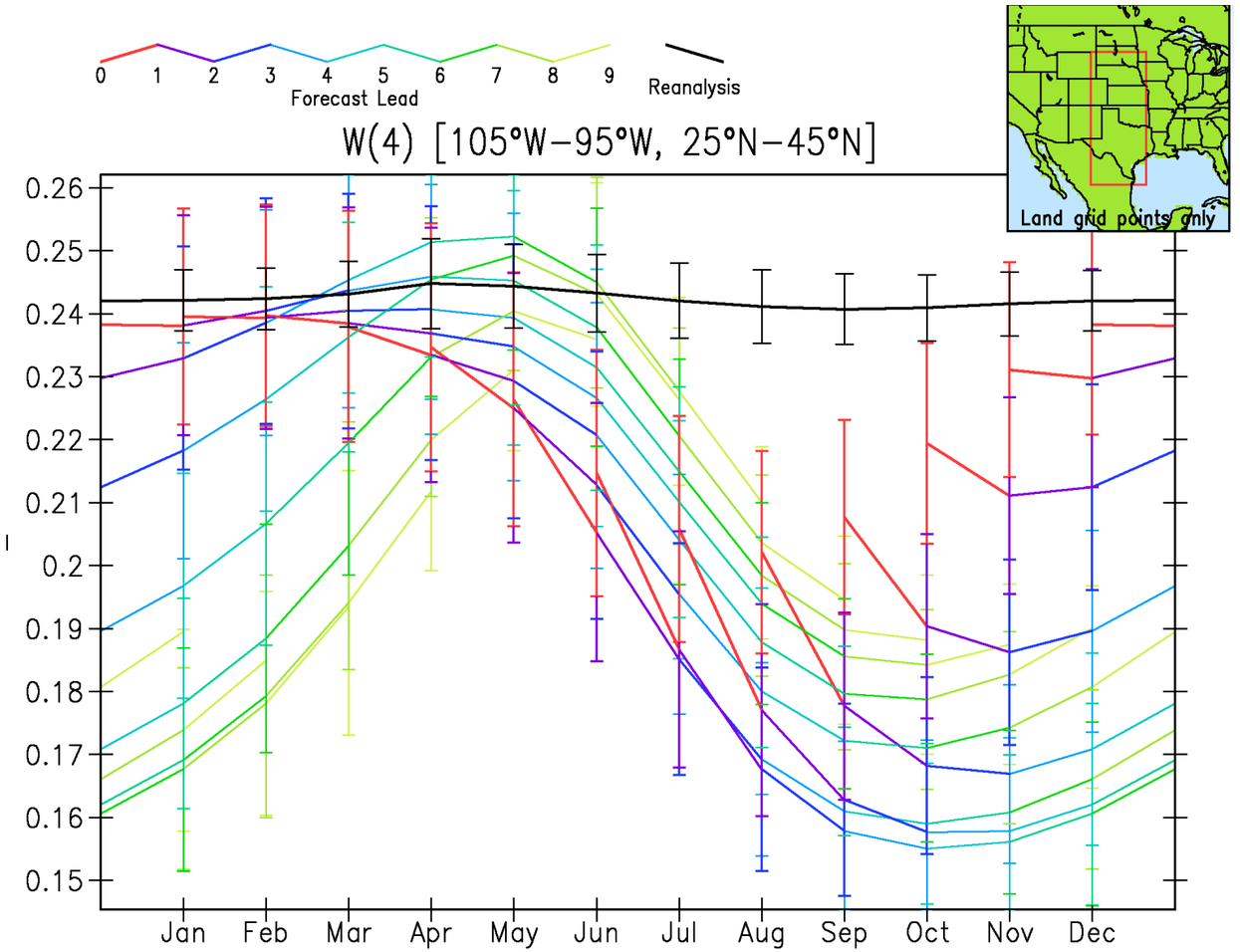
- Positive biases in CFSR through much of the year.
  - Reanalysis precipitation actually a bit low in MJJ, yet CFSR is high.
  - Throughout the year, precipitation simulations trend positive with increasing lead time.



Observations from the COOP/SnoTEL based PRISM monthly product

Deep Soil Behaves Quite Differently

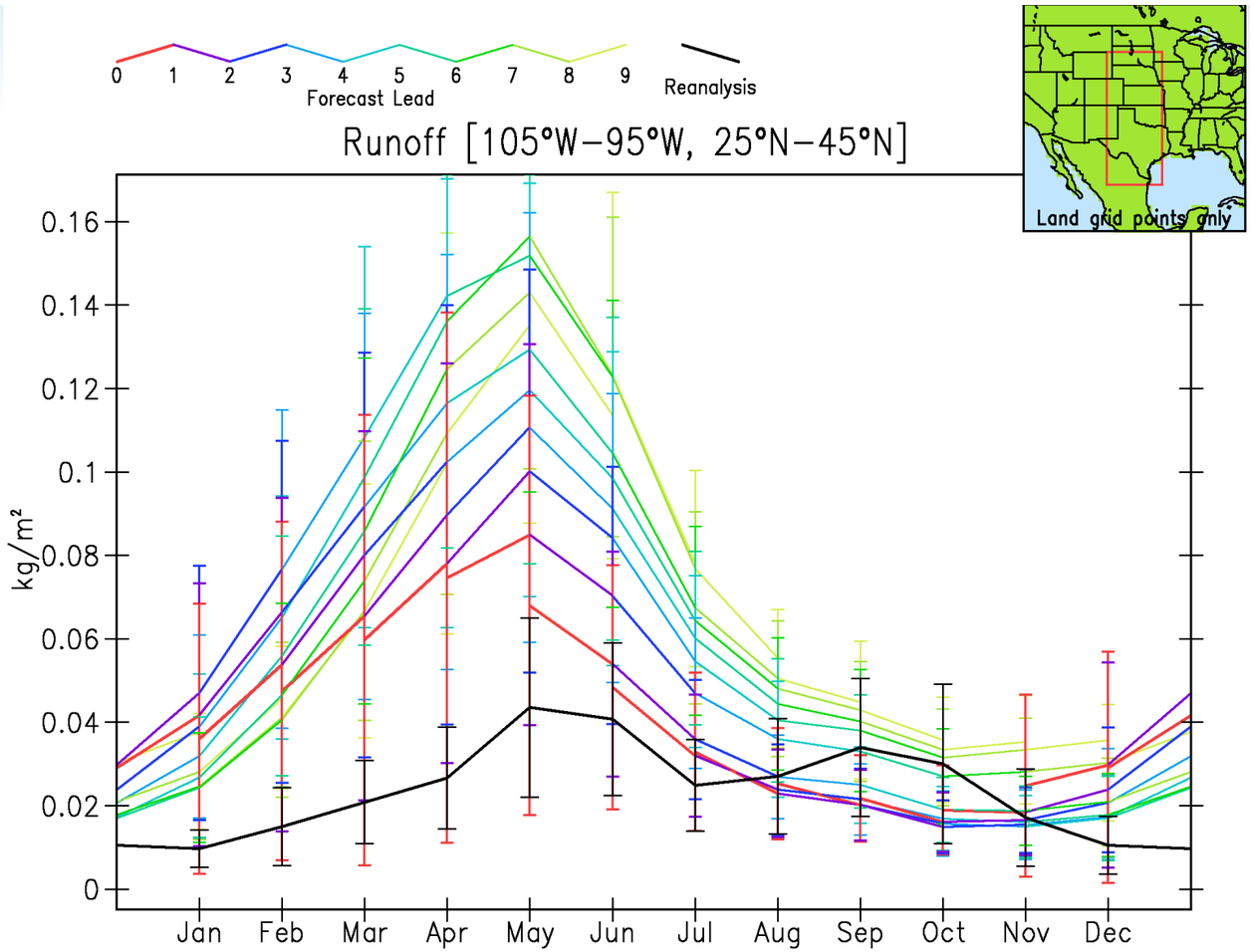
- Reanalysis (GLDAS) deep soil moisture is very flat.
- CFSR has a large annual cycle and an oscillation in the evolution of biases.



- Recall reanalysis states are constrained and there is no conservation enforced (characteristic of NWP's DAS).
- The reforecasts are in a model that (largely) closes the water budget.

Runoff

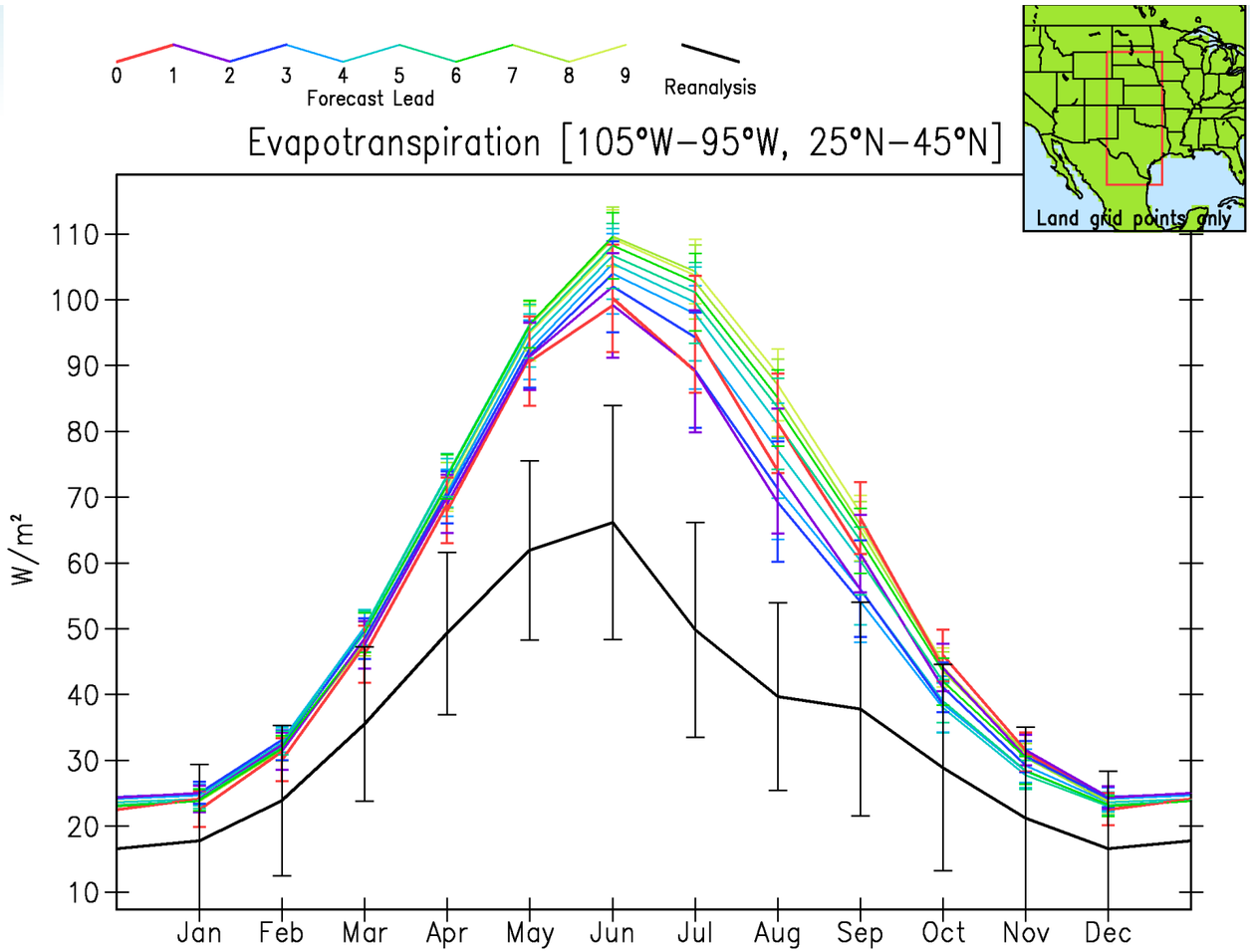
- CFSR output does not discern between baseflow and surface runoff, but we see the signature of precipitation biases.



- How can the hydrologic community make use of such data?

Evapotranspiration

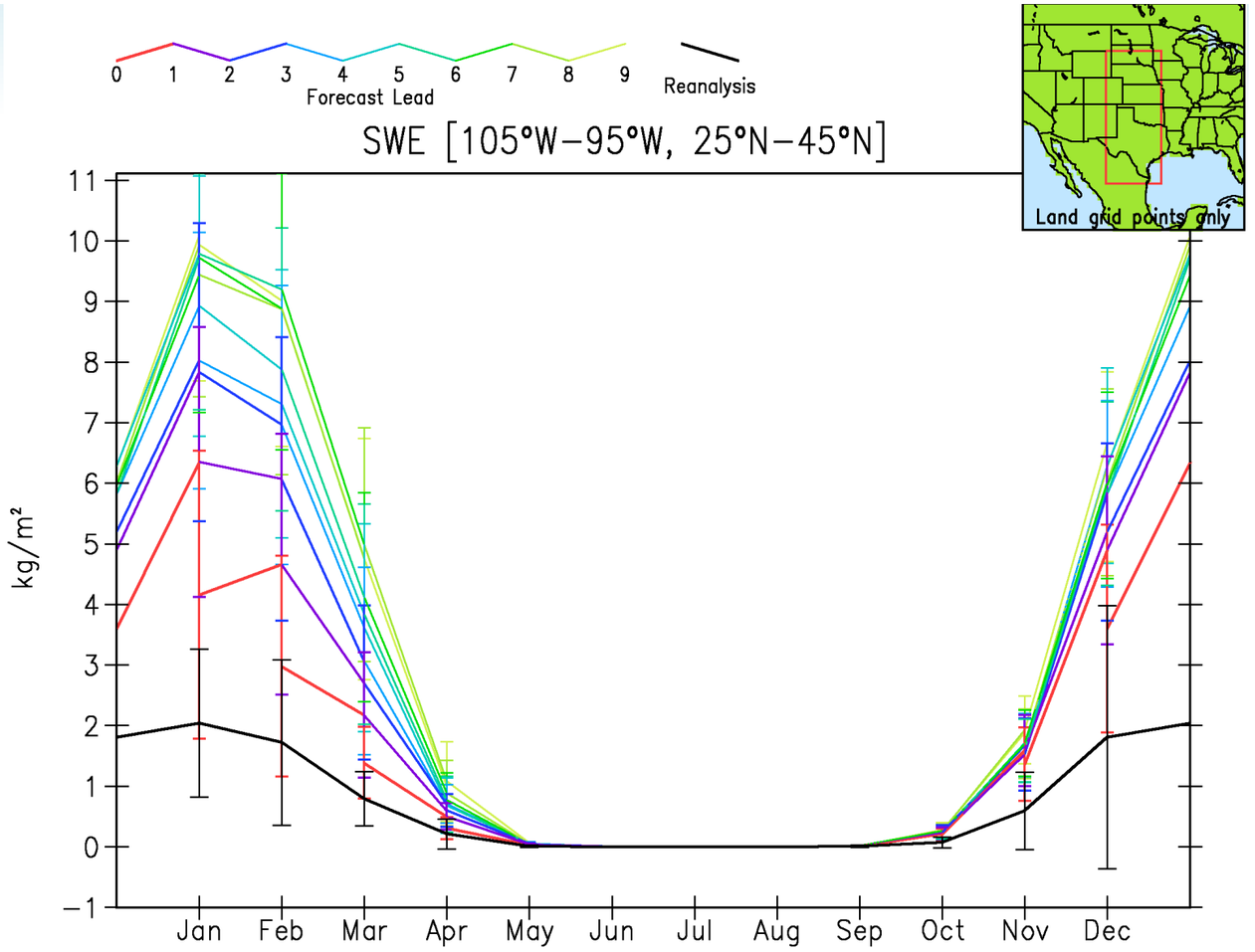
- CFSR ET is very high compared to the reanalysis.
- Recall CFSR SM is higher than in upper soil – source of extra ET.



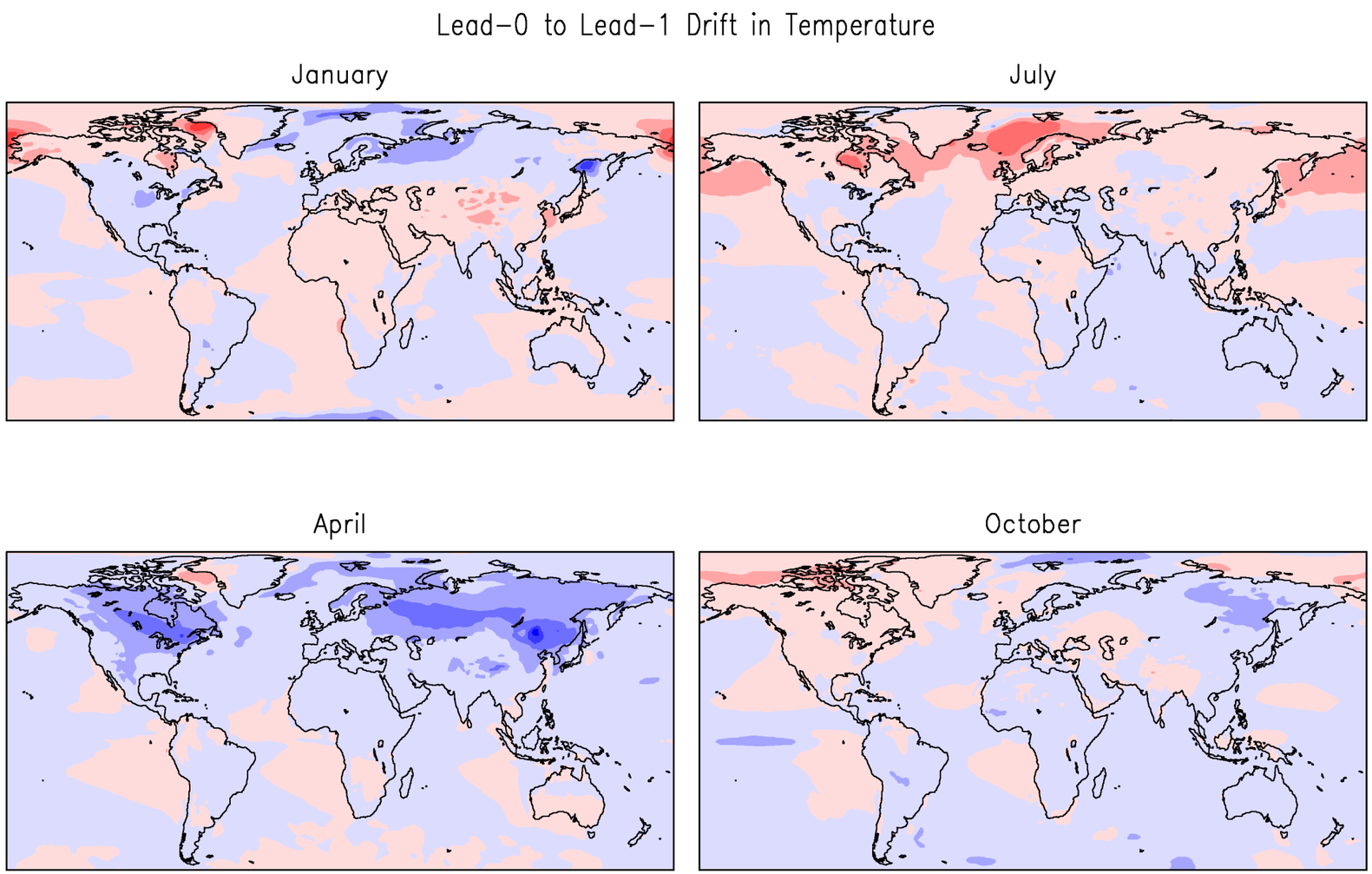
- Implication – negative increments in SM in reanalysis – soil constantly dried, this limits moisture for ET.
- Forecasts free to run up.

Snow – the Final Frontier(?)

- The largest biases (percentage) appear to be in snowfall / snow cover.
- Biases also across North America and Eurasia.
- All of these evolving biases in water budget terms pose challenges to users in hydrologic, agricultural, and related fields.

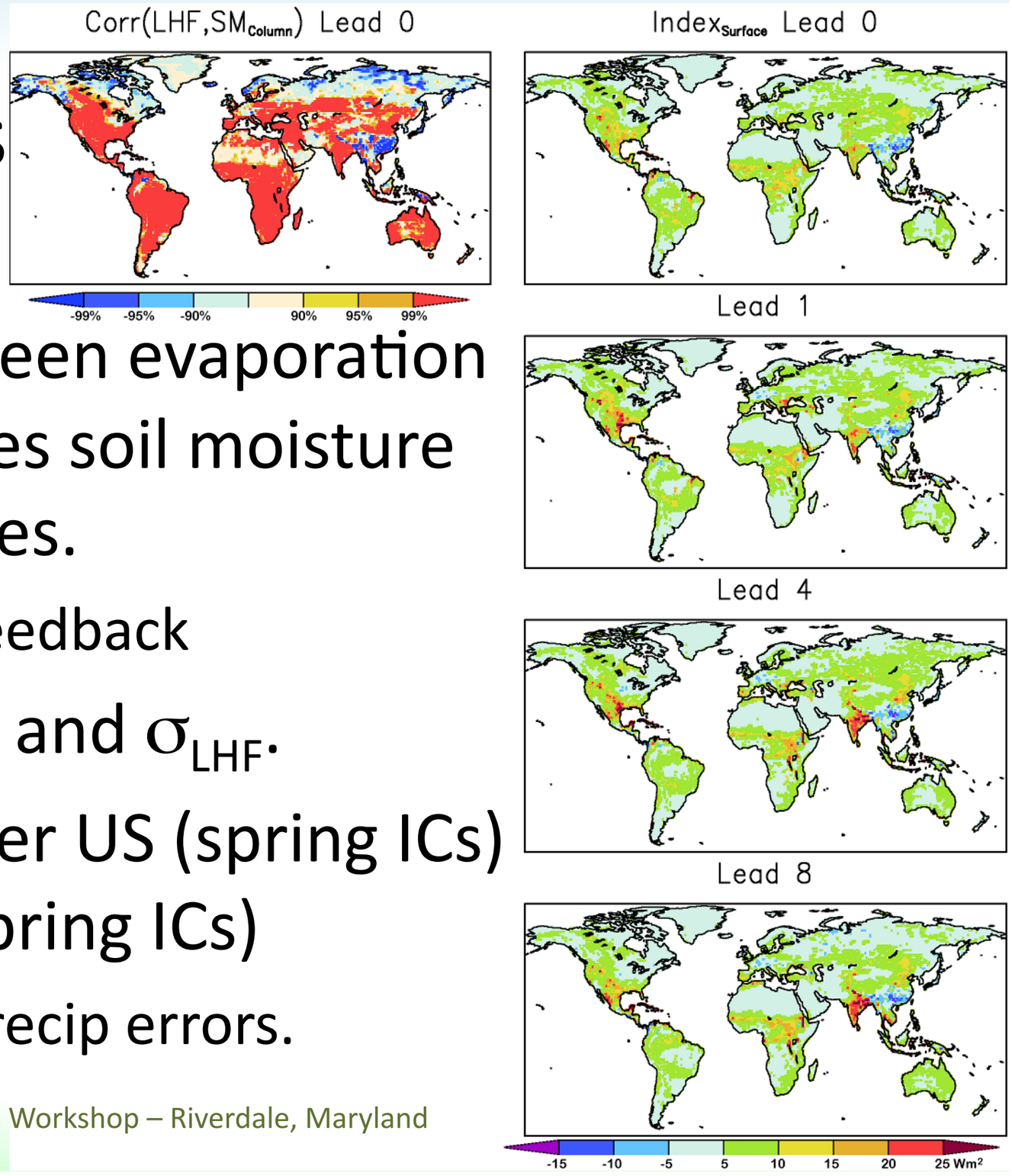


Snow Bias Signal in Temperature



- Heavy snow bias and late snow melt manifests as cold bias in spring.
- Evident in many other states and fluxes as well.

July Coupling Indices



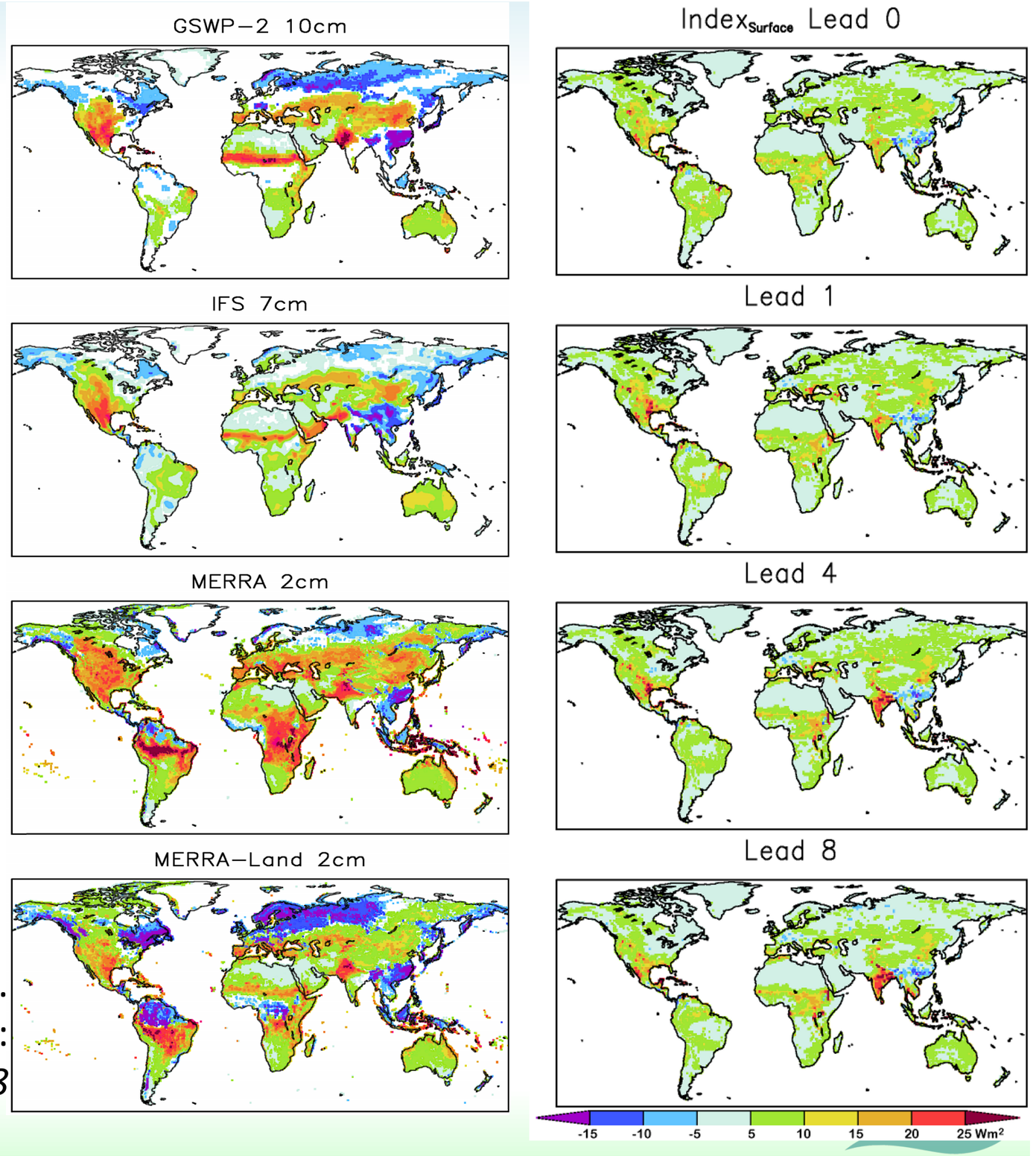
- Positive correlation between evaporation and soil moisture indicates soil moisture is controlling surface fluxes.
  - Necessary condition for feedback
- Index is product of $r_{LHF,SM}$ and σ_{LHF}.
- Index grows with lead over US (spring ICs) and India (winter-early spring ICs)
  - Indicative of systematic precip errors.

How Does CFSv2 Compare?

- Index for CFSv2 with Noah is considerably weaker (+&-) than:
  - GSWP-2 (Land MME)
  - IFS run in climate mode
  - MERRA reanalysis (both L-A and the land-only "replay").

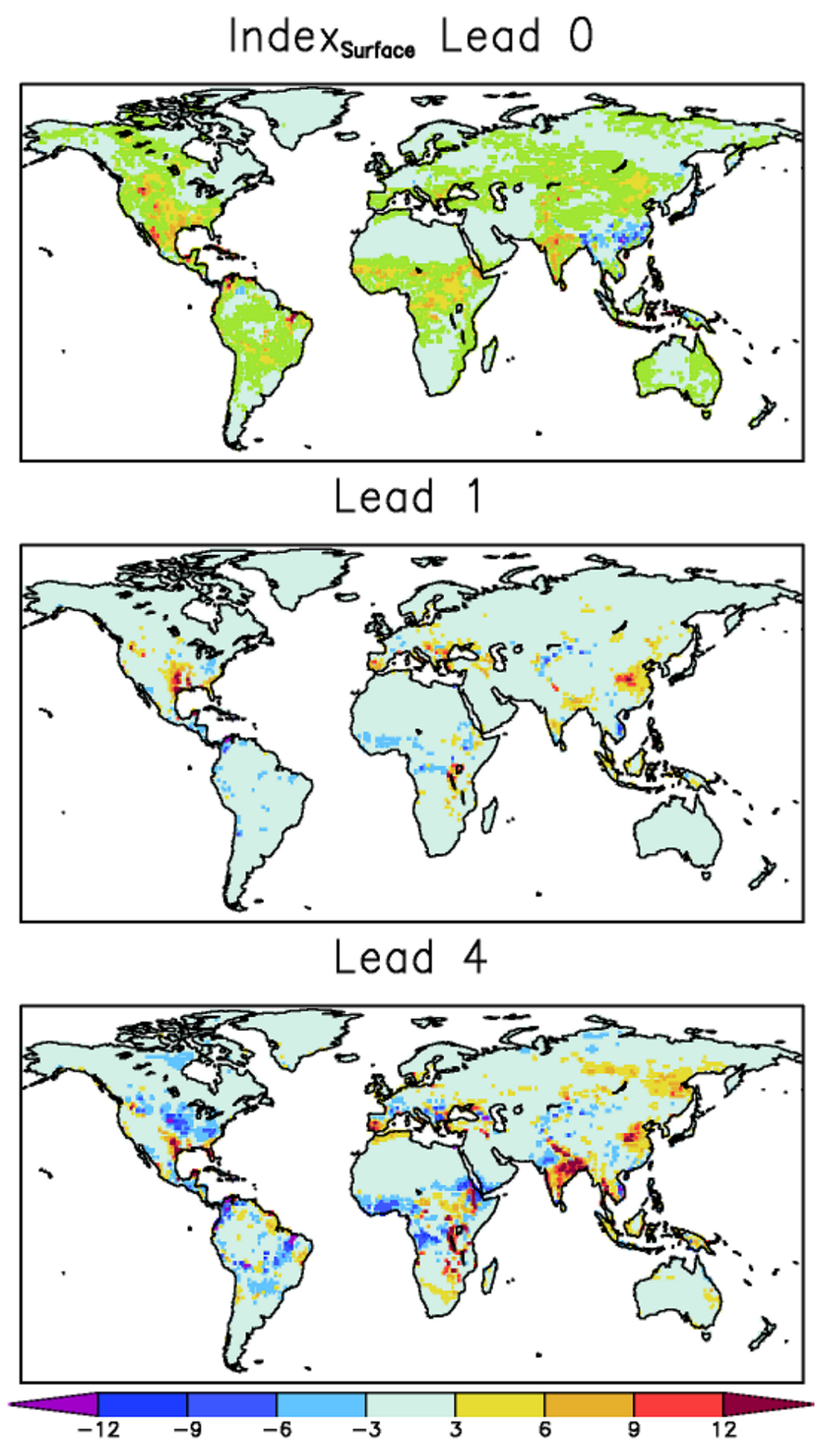
Still July….

Left panels from Dirmeyer (2011): *GRL doi:10.1029/2011GL048268*

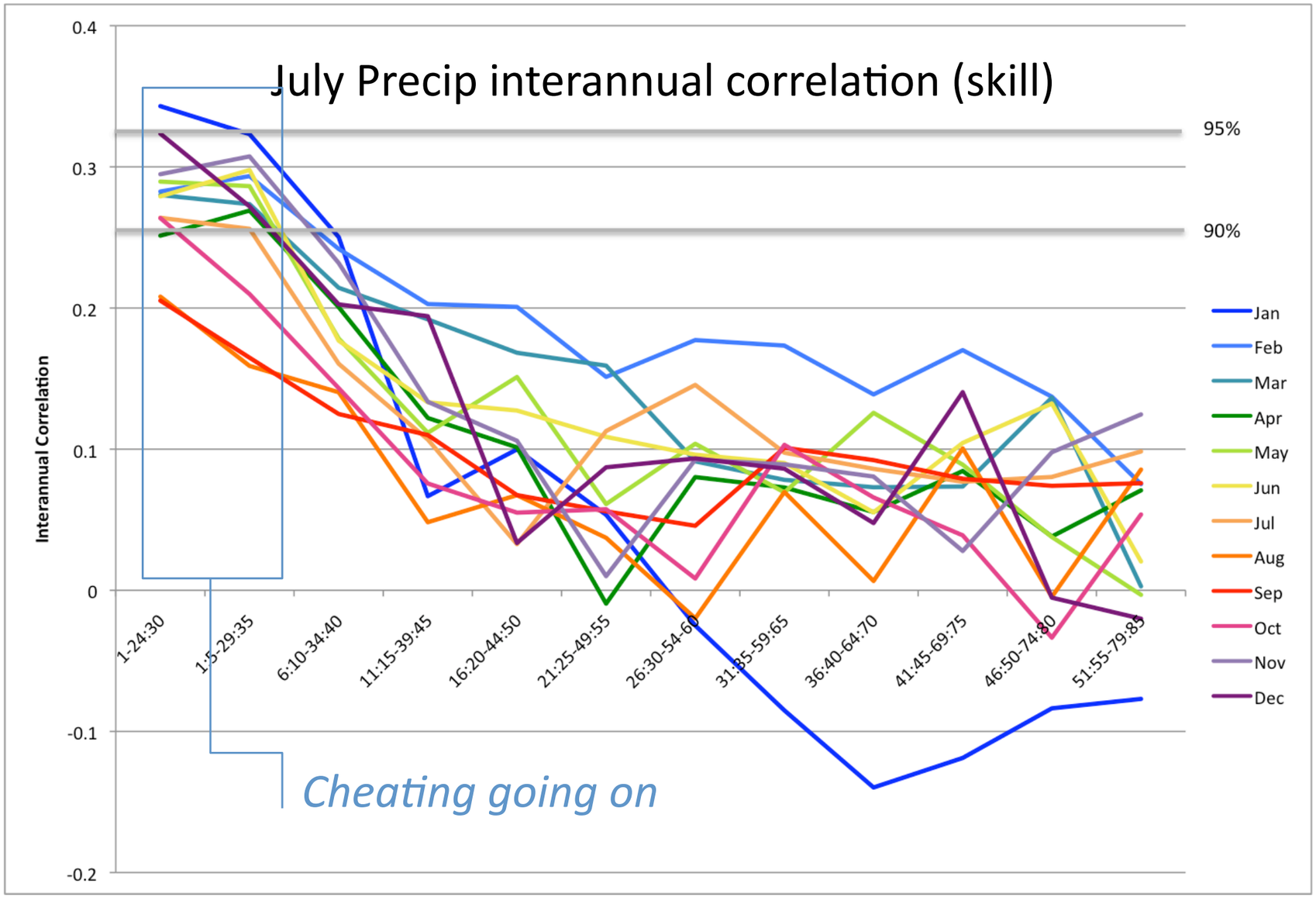


Drift in Coupling

- Changes in coupling index shows the southern Great Plains gets stronger, but much of the rest of North America has weakening coupling.
- These changes come because soil moisture drifts in/out of “sweet spot” for flux sensitivity.
- Could this contribute to reduced skill (cf GLACE-2)?

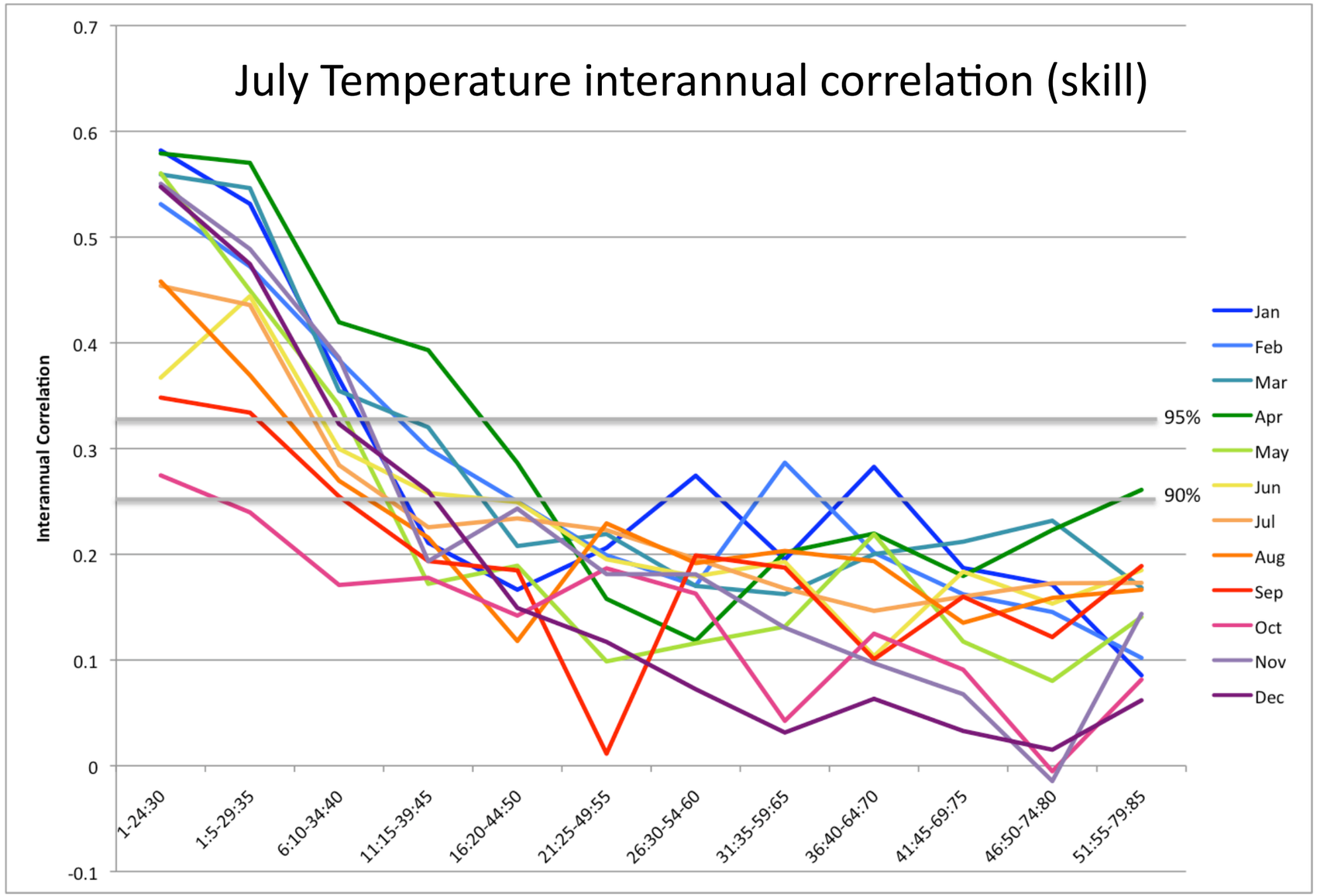


Precipitation Skill by Lead



- Staggering of ICs in ensembles allows for a pentad-level assessment of skill.
- Averaged over CONUS, little skill in <u>monthly</u> means.

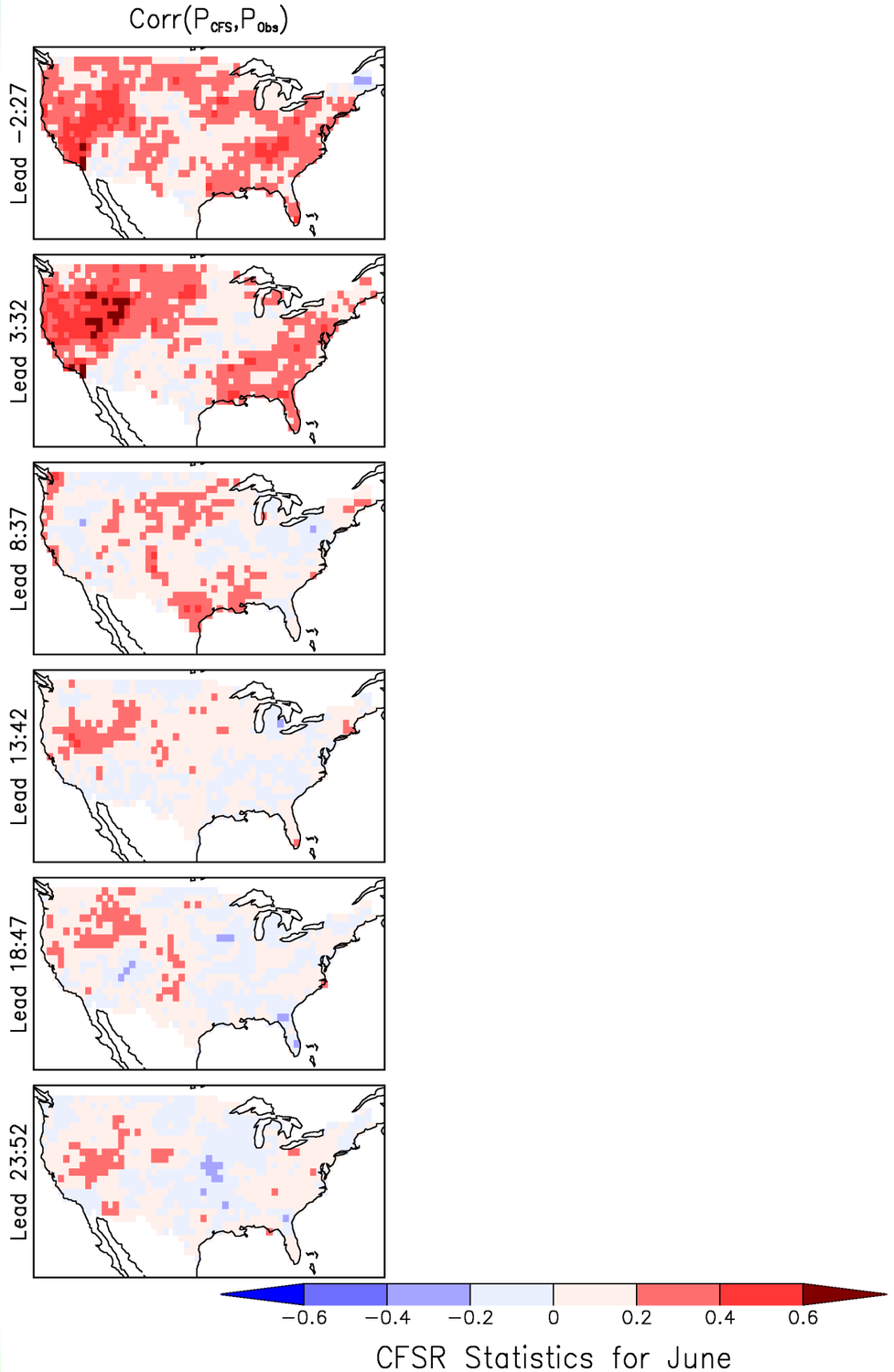
Temperature is Better



- Have yet to look at seasonal (3 month) skills – likely to be better than single month skills for both precipitation and temperature

Precipitation Validation and Soil Moisture ICs

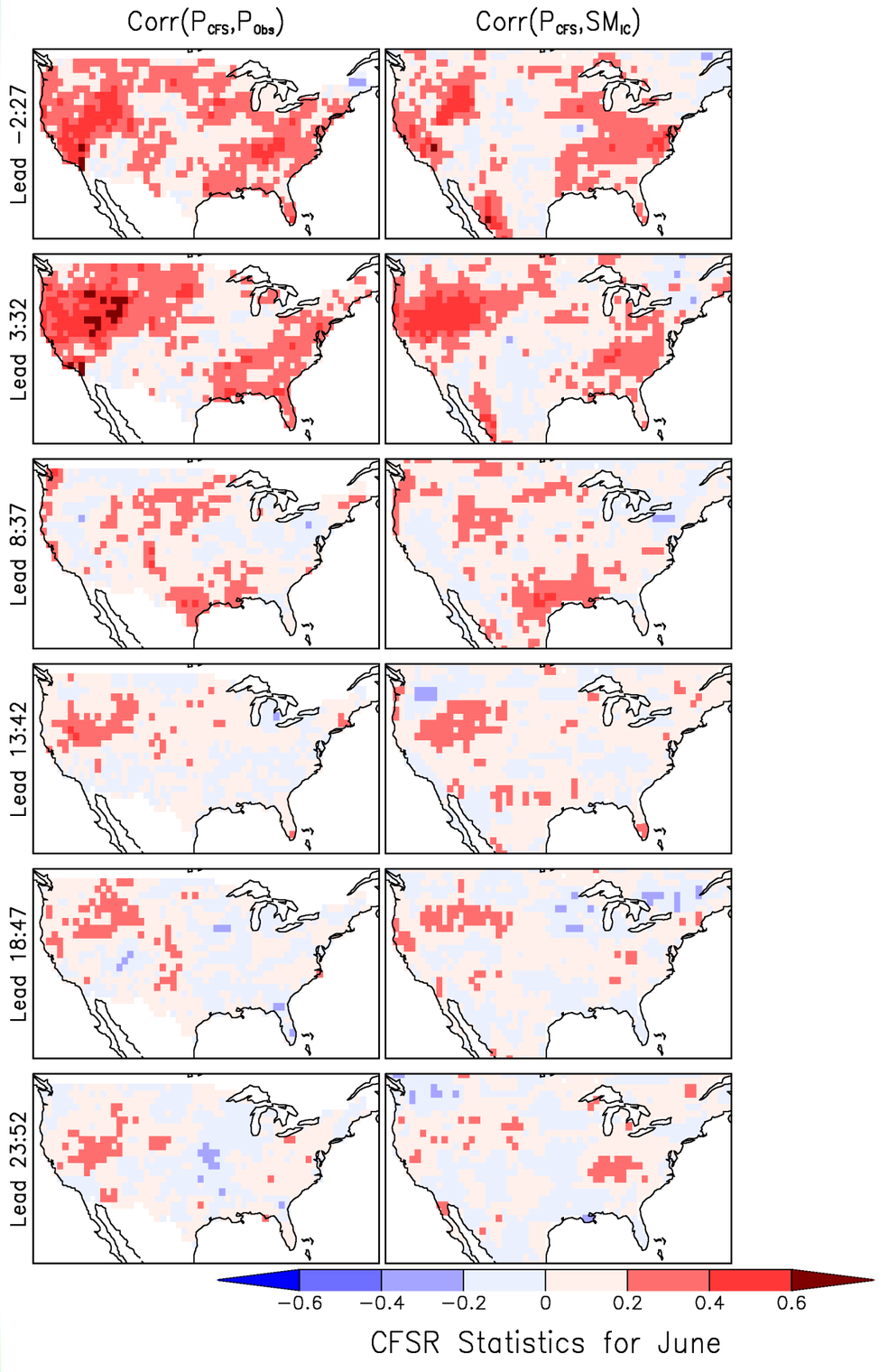
- CFSR monthly precipitation rapidly decorrelates from obs.



1 May 2012

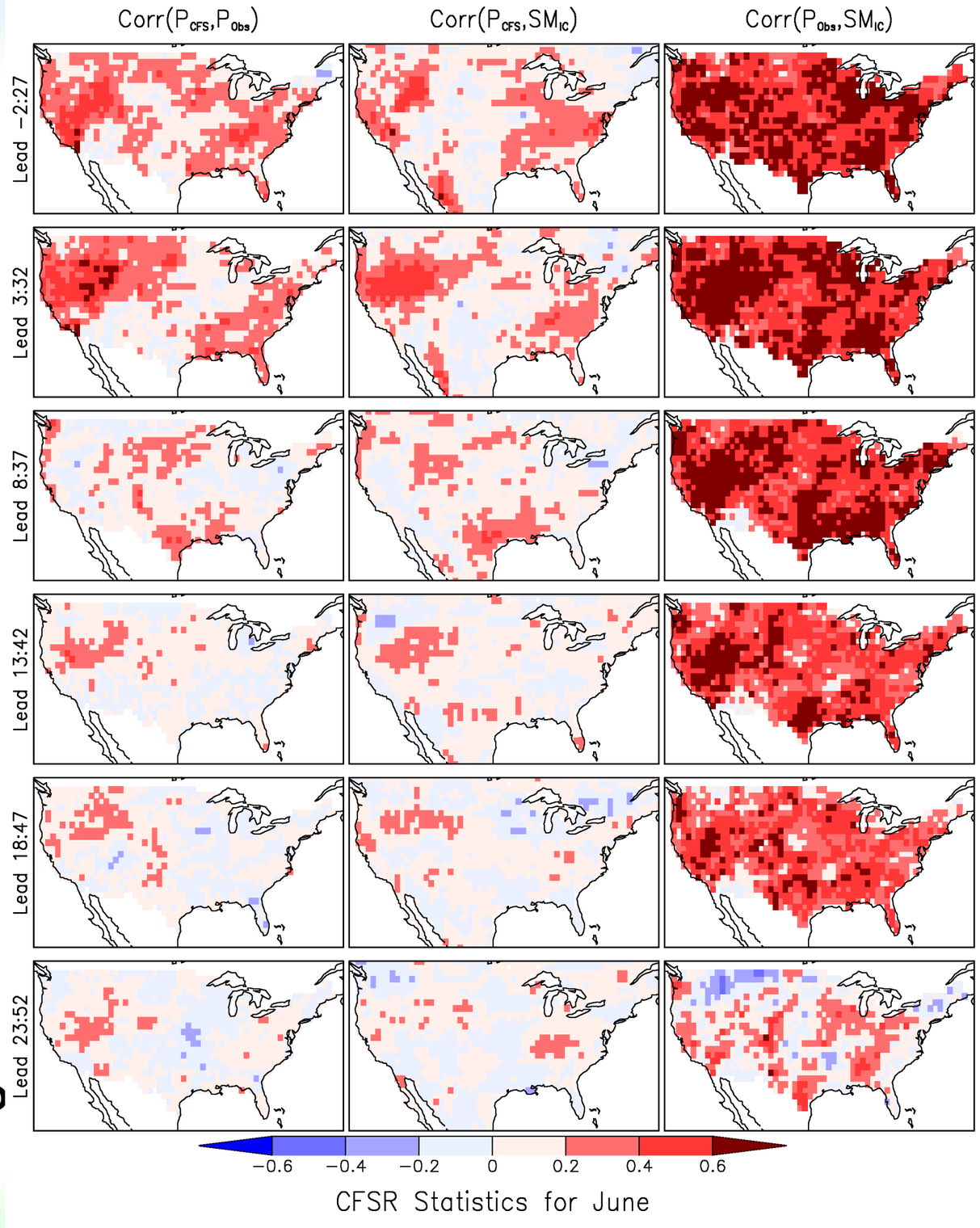
Precipitation Validation and Soil Moisture ICs

- CFSR monthly precipitation rapidly decorrelates from obs.
- CFSR precip similarly loses correlation with initial surface soil moisture anomalies.



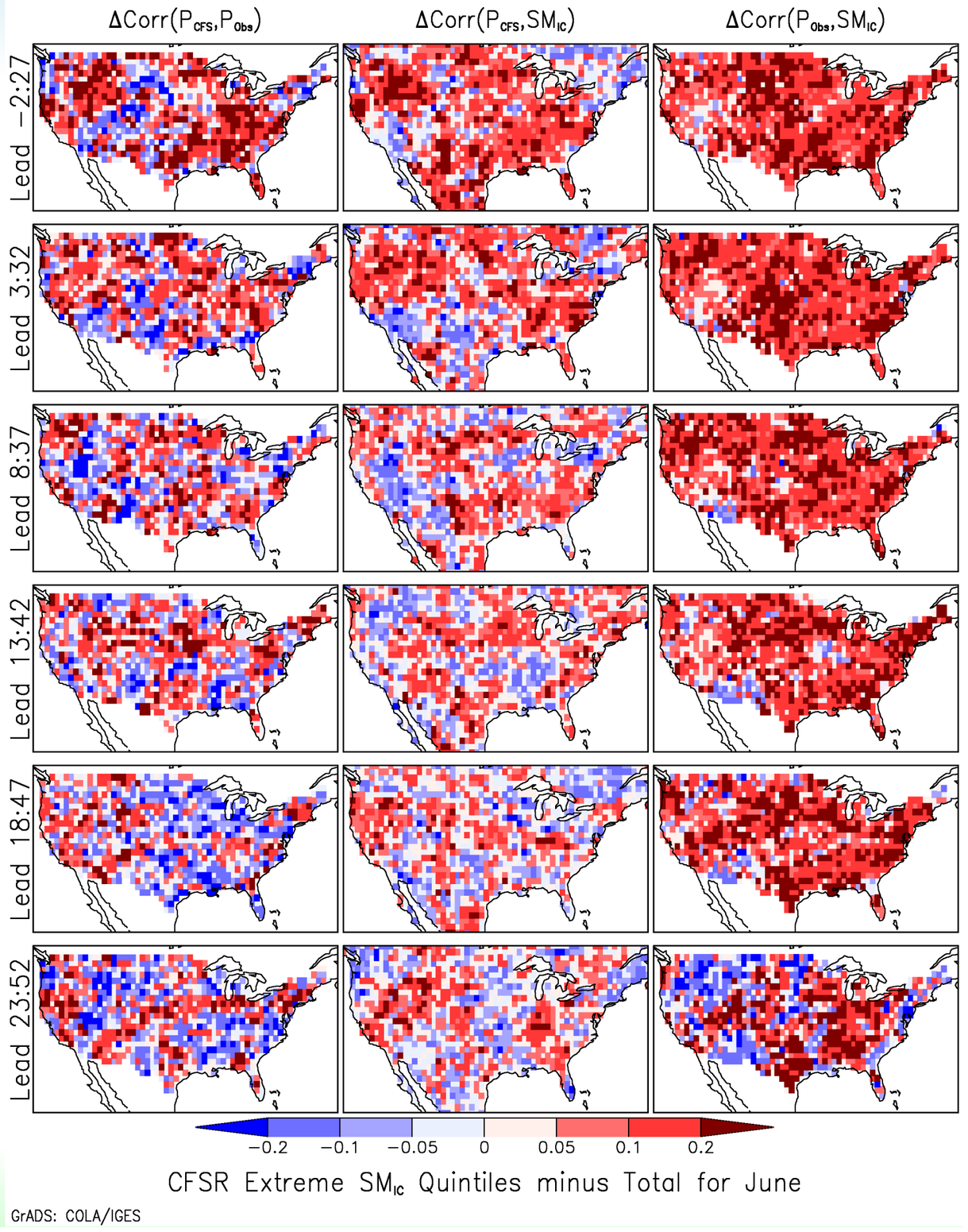
Precipitation Validation and Soil Moisture ICs

- CFSR monthly precipitation rapidly decorrelates from obs.
- CFSR precip similarly loses correlation with initial surface soil moisture anomalies.
- Observed precipitation has **much stronger** correlation with antecedent soil.
- Why? Positive L-A feedback, or persistent weather regimes?



And Extremes?

- Plots show the changes in correlation when only the forecasts with the driest/ wettest 20% of soil moisture ICs are used (compared to previous slide).
- More skill and connection of forecasts to SM_{IC}.
- Observations also show even stronger correlations.
- Still an open question: what is the cause?



Summary

- Huge drifts exist – CFSv2 climate is not naturally near the CFS Reanalysis climate. CFSv2 climatology varies in 2 time dimensions.
- Drifts and increments in state variables affect fluxes – this is very evident in local/regional water budgets.
- Land-atmosphere coupling metrics show patterns in good agreement with other global estimates, but generally weaker.
- Subsequent rainfall too weakly correlated with antecedent soil moisture
  - How much is weak coupling and how much is excessive high-frequency variability (or is variance simply following excessive mean rainfall)?